Feb 24, 1942. B. F. MIESSNER 2,273,975

APPARATUS FOR THE PRODUCTION OF MUSIC

Filed Nov. 30, 1938 2 Sheets-Sheet 1

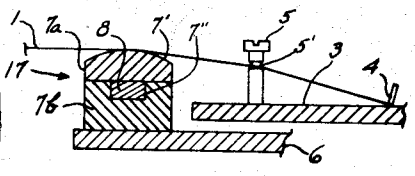


Fig. 1a

Fig. 1

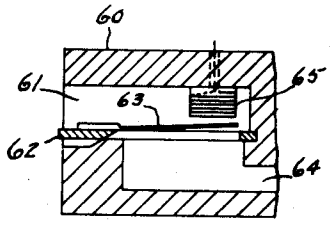
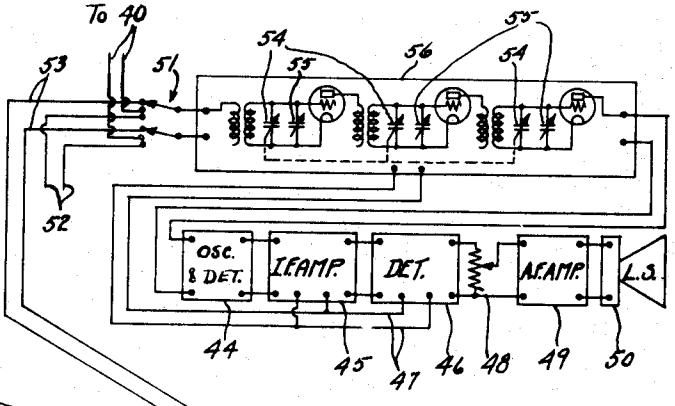


Fig. 2



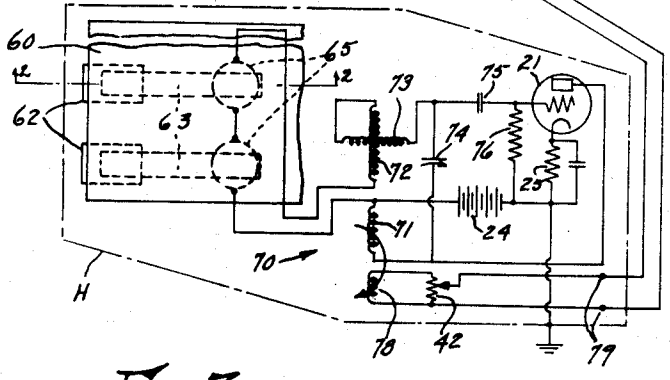


Fig. 3

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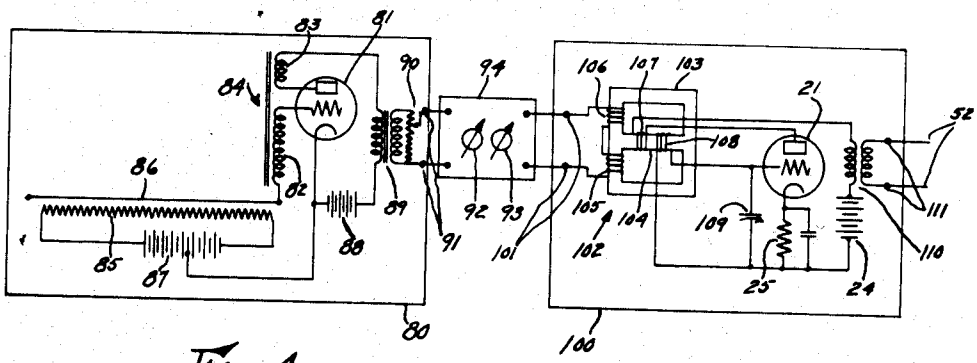


Fig. 4

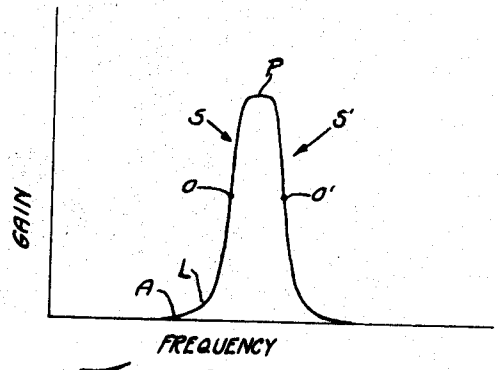


Fig. 5

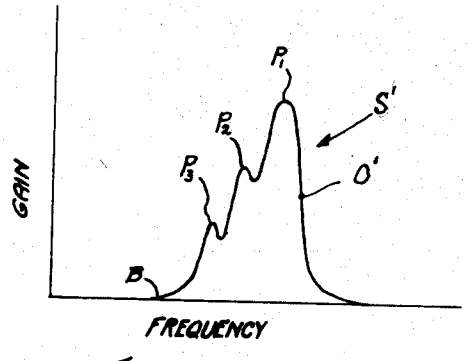


Fig. 6

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UNITED STATES PATENT OFFICE

2,273,975

APPARATUS FOR THE PRODUCTION OF MUSIC

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Application November 30, 1938, Serial No. 243,127

21 Claims. (Cl. 84—1.14)

This invention relates to methods and apparatus for the production of music, and more particularly for that production by electrical means from the oscillations of low-frequency oscillator means selectively operable at a plurality of frequencies. According to one typical embodiment of the invention the low-frequency oscillator means may comprise a series of progressively tuned mechanical oscillators or vibrators, selectively vibratable in accordance with chordal or solo music to be played; while according to another typical embodiment the low-frequency oscillator means may comprise a single oscillator, either mechanical or electrical, subject to selective tuning to various frequencies and operable at those frequencies selectively in accordance with solo music to be played.

It is an object of the invention to provide a musical instrument wherein the output tones are derived from the oscillations of the low-frequency oscillator means by relatively simple or inexpensive, yet highly efficient, electrical means.

It is an object to provide an improved instrument of the type wherein the low-frequency oscillator means modulates the oscillations of a high-frequency oscillator.

It is an object to provide an improved instrument in which there may be effectively utilized large portions, or the entirety, of the apparatus conventionally embodied in a radio receiver.

It is an object to provide an instrument wherein the output tone quality may be widely varied by particularly simple and effective means, and control means appropriate to such variation.

It is an object to provide an improved arrangement of an electrode with the vibrators of the instrument.

Other and allied objects will more fully appear from the following description and the appended claims.

In the description reference is had to the accompanying drawings, of which:

Figure 1 is a view, with a portion in perspective but principally diagrammatic, of a musical instrument wherein my invention has been embodied;

Figure 1*a* is an enlarged detail showing of the bridge;

Figure 2 is a cross-sectional view taken along the line 2—2 of Figure 3;

Figure 3 is a view, with a portion in plan but principally diagrammatic, of a musical instrument wherein my invention has been embodied in a modified form in respect of certain of its components;

Figure 4 is a diagrammatic view of a portion of a musical instrument wherein my invention has been embodied in a further modified form as respects certain components;

Figure 5 is a typical curve or transmission-frequency characteristic of the amplifier of Figure 1 or Figure 3; and

Figure 6 is a typical curve or characteristic of the amplifier of Figure 3 with a special adjustment of certain of its controls.

According to certain aspects of the invention set forth in my application Serial No. 84,728, filed June 11, 1936, now Patent No. 2,140,025, granted December 13, 1938, I directly modulated high-frequency oscillations by the vibrations of a tuned vibrator or series of tuned vibrators, thereafter amplifying the modulated oscillations, demodulating them to produce audio frequency oscillations representing the original vibrations, and further amplifiying the audio frequency oscillations before their translation into sound. This procedure has certain advantages over the simple translation of audio frequency oscillations from the vibrators and the simple amplification of those oscillations, among which advantages are the distribution of the total amplification over two or more frequency spectra (with attendant reduction of feed-back and noise and other difficulties), and the economical availability of much of the apparatus required for the electrical musical instrument for radio reception purposes, or vice versa. In the case wherein electrodes adjacent the vibrators are to be employed in either the modulating or the simple audio translating procedure, the former has the further advantages of substantially eliminating the often troublesome effects of leakage between vibrator and electrode and the attendant requirement for very high insulation resistance under actual operating conditions, and of providing as efficient action at low as at high audio frequencies.

The type of modulation which was particularly described and illustrated in the co-pending application abovementioned was amplitude modulation. I have found, however, that the tuned vibrators of a musical instrument are surprisingly well adapted to be physically related to the tuned circuit of a high-frequency electrical oscillator so as to modulate its frequency; and that when the modulation is effected in this manner, and the modulated oscillations applied to amplifying and demodulating apparatus no more special than that of a good-quality radio receiver, exceptionally high sensitivities may be obtained and other advantages secured, without loss of any of

the advantages which flow from the modulation procedure broadly.

In Figure 1 I have illustrated the instant invention as applied for example to an instrument of the piano type. Reference being had to that figure, there will be seen a plurality of progressively tuned vibrators in the form of strings 1, each strung from a respective hitch pin 4 in metallic frame 3 across the common bridge 7 to a front bearing and respective tuning pin not herein necessary to show. While I intend no unnecessary limitation to the manner of exciting the vibrators, I may for example employ with the strings of the instrument of Figure 1 a striking and damping action of conventional piano variety, this having been indicated by the showing of a respective hammer 2 associated with each string. The bridge 7 is preferably vibratally supported; and while this may be done in any manner, I have shown it supported on a vibratile plate 6 spacedly secured to the bottom of frame 3 and extending forwardly in cantilever to support the bridge, as described and claimed in my application Serial No. 229,650, filed September 13, 1938, now Patent No. 2,225,195, granted December 17, 1940.

In this embodiment the strings 1 are physically related to the tuned circuit of a high frequency oscillator by the use of the strings as an electrode of one or more capacities which are directly included in the tuning circuit of the oscillator and are varied by and in accordance with the string vibration. One such capacity may be formed by the strings and an electrode system 11 positioned thereabove in spaced relationship thereto, somewhat forwardly of the bridge 7; and while this electrode system may be of any known form, I have for simplicity shown it as a narrow conductive strip 12 secured to the bottom edge of a thin strip 13 of insulating material, which in turn may be supported (e. g., to the bridge) in any convenient manner. Another such capacity may be formed by the strings and an electrode system 14 positioned therebelow (for example directly underneath the electrode system 11 just mentioned); again purely by way of example, the electrode system 14 may be similar in construction to the system 11, comprising a narrow conductive strip 15 secured to the top edge of a thin strip 16 of insulating material, which in turn may be supported similarly to the strip 13. The capacities between strings and electrode systems 11 and 14 are varied by the string vibrations in an obvious manner.

Still another capacity varied by and in accordance with string vibration may be formed by the strings and an electrode system 17 immediately associated with the bridge 7; this system I have illustrated (in the enlarged Figure 1a as well as in Figure 1) as a conductive strip or bar 8 positioned between the separately formed top bridge portion 7a and bottom bridge portion 7b, for example in a recess 7'' in the top of the latter. The bridge portions are formed of insulating material, and at least the top portion 7a of such material having a relatively high dielectric constant—for example, a phenol-resin composition such as is commonly termed "Bakelite." The top surface 7' of the top bridge portion 7a, on which the strings bear, is convex and extends at least a short distance forwardly of the most forward point of actual contact with the bridge. When the string—in particular its portion forward of the bridge 7—vibrates vertically, the string portion above the bridge but not actually in contact therewith moves oscillatorily toward and away from the bridge surface 7', and the length of the string portion actually in contact with that surface may execute a minute oscillatory variation; these actions are the equivalent of an oscillatory variation of the average spacing of the string from the surface 7'. Because of the relatively high dielectric constant of the top bridge portion 7a, the oscillatory variation just mentioned is of several times the effect on the capacity between strings and bar 8 that it otherwise would have, and that capacity is accordingly varied oscillatorily in a surprisingly efficient manner. (It is possible that oscillatory compression variations in the top bridge portion 7a may be of sufficient degree to exert at least a slight aiding influence in the oscillatory capacity variation.) It may be pointed out that the enclosure of the actual conductive element or bar 8 not only eliminates ordinary leakage difficulties, but also that troublesome phenomenon of noise-producing leakage variation occurring as moisture progressively deposits on or evaporates from an exposed insulating surface joining two intendedly isolated electrodes; and that the structure, while particularly useful herein, may also be utilized to advantage in other systems.

In connection with a bridge-associated electrode system of the type of 17, I have found that a significant adjustment of tone quality of finally produced sound may be effected by an adjustment of the angle of bearing of the string on the bridge; change of this bearing changes the pressure and mean length of contact of the string against the surface 7', and thereby influences the capacity variation for given string vibrational characteristics, and probably also to some extent directly influences those vibrational characteristics. Accordingly I have shown each string, between bridge and hitch pin, resting in a circumferential groove 5' in a respective vertical screw 5, the screw being vertically adjustable in frame 3 to raise or lower that groove and hence the string.

The high frequency oscillator into which the capacities between the strings and the several electrode systems are connected appears as 20. By way of example it has been illustrated as including a 3-element repeater tube 21; an inductance coil 22 connected in the input circuit of the tube; an inductance coil 23 connected in the output circuit of the tube and variably coupled to the coil 22; a source 24 of plate potential included in the output circuit; and a by-pass bias resistance 25 common to input and output circuits. The total capacity which, with coil 22, forms the tuning circuit of the oscillator, includes variable condenser 26 shunted across that coil; it also is made to include the several capacities between strings and electrode systems by the appropriate connection of those capacities with the condenser 26. While this connection may be carried out in any of a variety of manners, I have illustrated it as follows:

The strings 1 are connected to the rotor plate 28 of the condenser 26 by such connection of the metallic frame 3 with which the strings make electrical contact through the hitch pins. The conductive strips 12 and 15 of the electrode systems 11 and 14 are connected to the respective stator plates 31 and 32 of a condenser 30, whose rotor plate 33 may be brought wholly opposite stator plate 28, wholly opposite stator plate 29, or opposite both in any desired relative proportions. The rotor plate 33 and the conductive bar

8 of the electrode system 17 are connected to the respective stator plates 35 and 36 of a condenser 34, whose rotor plate 37 may be brought wholly opposite stator plate 35, wholly opposite stator plate 36, or opposite both in any desired relative proportions. The rotor plate 37 is connected through a variable condenser 38 to the stator plate 27 of the condenser 26.

With the coupling of coil 23 to coil 22 suitably adjusted, the oscillator 20 will operate at an average frequency determined by the capacity values of the several condensers and the average or mean values of the several capacities between strings and electrode systems. Upon vibration of any string or strings, the oscillatory variations of the last-mentioned capacities will oscillatorily vary the total tuning capacity of the oscillator and hence the frequency of its oscillation. While the amplitude of that oscillation will be utterly negligibly affected, the amplitude, frequencies and waveforms of the swings of oscillator frequency will be directly responsive to the amplitudes, frequencies and waveforms of the string vibrations as seen by the electrode systems.

Frequency-modulated oscillations from the oscillator 20 are made available at the output terminals 40 of that oscillator in any convenient manner, as by the connection to those terminals of a coil 41 coupled to the coil 22. To control the amplitude of the output oscillations the coupling of coils 41 and 22 may be made variable, and additionally or alternatively a potentiometer 42 may be interposed between coil 41 and those output terminals. Suitable electrostatic shielding H may be disposed about the oscillator, including the capacities between the strings and the several electrode systems; this shielding may be connected with the strings, and may be grounded if desired.

Figure 1 shows the output terminals 40 supplying output oscillations to the input of a tuned amplifier 45, which may be the so-called "intermediate-frequency" amplifier of a superheterodyne radio receiver; this supply has been shown as effected by conductors 43, though no limitation to pure conductive connection is intended. The amplifier 45 may be followed in cascade by detector or demodulator 46, potentiometer or volume control 48, audio frequency amplifier 49, and loudspeaker or other electro-acoustic translating device 50; the detector 46 may if desired be arranged to feed back a signal-derived control voltage to the intermediate-frequency amplifier 45 for automatic volume control action in well understood manner, as indicated in Figure 1 by the conductors 47.

The transmission-frequency characteristic of the amplifier should have a slope within the range through which the oscillator frequency swings. To arrange for this the oscillator 20 may for example be operated at an average frequency displaced somewhat from the frequency of maximum transmission through the amplifier; this has been indicated in Figure 5, wherein the curve A is a typical gain- or transmission-frequency characteristic of the amplifier 45. The frequency of the peak P of the curve is of course the frequency to which the amplifier is tuned; the frequency of either the point O or the point O' may represent the mean frequency of operation of the oscillator, at which frequency the amplifier delivers the oscillations to the detector with only partial gain. From the curve A it will be understood that as the oscillator frequency oscillatorily swings up and down from that of the point O (or O') in representation of vibrator vibration, the amplitude with which the oscillations are delivered to the detector will be subjected to a corresponding oscillatory variation; the demodulating action of the detector converts this variation into corresponding audio frequency oscillations, which may be controlled in amplitude by the potentiometer 48, amplified by the amplifier 49, and converted into sound by the loudspeaker 50.

It will of course be understood that the degree of slope of the curve A within the region of frequency swing has a direct influence on the efficiency of the system; and the steepness of the sides S and S' of this curve in typical inexpensive radio equipment, particularly of the superheterodyne variety, makes possible an extremely efficient system at low cost.

The mean tuning of the oscillator, to the frequency of point O or O' for example, may be effected primarily by variation of the capacity of condenser 26. If the point O (or O') is selected to lie rather centrally of one of the relatively straight side portions S and S' of the curve A, there may be obtained an essentially linear relationship of amplitude variations at the detector to the frequency swings which produce them, so long as the frequency swings are not permitted to rise to too high magnitudes. The magnitudes of the frequency swings may be controlled by a control of the relative values of the capacity of condenser 26 and the other capacities included in the oscillator circuit. Thus an increase of frequency swing magnitude may be effected by an increase of the capacity of condenser 38 and a reduction of the capacity of condenser 26; such respective increase and decrease may be effected in such relative degree as to keep constant the total mean capacity and hence mean frequency of the oscillator. Conversely, a decrease of frequency swing magnitude may be effected by a decrease of the capacity of condenser 38 and an increase of the capacity of condenser 26. These two condensers may of course be appropriately interlinked, if desired, for the joint actions just described.

Adjustment of either of the condensers 30 and 34, while it may necessitate slight readjustment of either one of the condensers 26 or 38 relative to the other to preserve precisely a predetermined mean frequency, will not materially change that frequency; these condensers are provided as quality, rather than frequency, controls. Thus movement of the rotor plate 37 of condenser 34 will progressively vary the relative contributions, to the waveforms of the frequency swings, of the capacity between the strings and electrode system 17 on the one hand and the capacity between the strings and the electrode systems 11 and 14 on the other. Correspondingly, movement of the rotor plate 33 of condenser 30 will progressively vary the relative contributions, to the waveform of the frequency swings, of the capacity between strings and electrode system 11 and the capacity between strings and electrode system 14. Because of the difference in vibrational waveform of the strings between their end portions (above bridge 7) and their portions adjacent the electrode systems 11 and 14, and because of the phase opposition of the vibration-produced variation of string capacity to the latter two systems, the rotor plates 33 and 37 will be understood to act as effective controls of the waveform of the swings of frequency of the oscillator and hence of the finally produced sound. Broadly, these rotor plates represent the adaptation to the in-

stant system of the amplitude and phase controls disclosed, in U. S. Patent No. 1,906,607 to Jacobs, for a plurality of translating devices variously associated with a single string or other vibrator; and my invention contemplates generally any such adaptation, wherein each vibrator is physically related at a plurality of its portions to the tuned circuit of the oscillator, preferably with selective control as to the various portions.

Figure 1 has illustrated my invention in one simple form, but its details will be understood not to be limitative. Thus for example there may be employed other low frequency oscillator means, and in a specific aspect other vibrators, than strings; other manners of causing the frequency of the high frequency oscillator to be varied by the low frequency oscillator, and in a specific aspect other physical relationships of vibrator to tuned circuit; other oscillation-transmitting means than the simple intermediate-frequency amplifier **45**; etc. Typical such variations I have illustrated in Figure 3. It will be understood, however, that the particular groupings of features in these figures is not intended to be limitative, as has been partially indicated by the switch **51** in Figure 3, which may be thrown to connect to the oscillation-transmitting means of Figure 3 the oscillator output terminals **40** of Figure 1.

The vibrators shown in Figure 3 are tuned reeds, which themselves are better seen in the cross-sectional Figure 2. In these figures a reed housing is shown as **60**, provided with a plurality of cells **61** into each of which may be inserted a respective apertured reed base **62** to which is secured one end of a respective tuned metallic reed **63** extending across the aperture in base **62**; this aperture communicates with a respective air duct **64**, air being movable through the several ducts selectively, to vibrate the several reeds in accordance with music to be played, by a conventional organ air system not herein necessary to show.

The high frequency oscillator **70** in Figure 3 has been shown by way of example as of modified form. It may comprise the tube **21**, provided with grid leak and condenser **76** and **75**, and if desired with the by-passed bias resistance **25**. From grid to plate of the tube is connected the tuning condenser **74**, shunted by a series of coils including **71**, **72** and **73** to form the tuned circuit of the oscillator; the source **24** of plate potential for the tube may be connected into the series of coils, for example so as to cause coil **71** to lie in the plate or output circuit, and the other coils in the input circuit, of the tube. This oscillator is basically of well-known form, in which the coupling between output and input circuits may be a fixed coupling of relatively high value.

The physical relating of the vibrators to the tuned circuit of the oscillator in Figure 3 is effected by including in that circuit, in series with the input circuit coils **72** and **73** for example, a group of small coils **65**, themselves interconnected for example in series. The coils **65**, each of which may typically comprise a few turns of wire, are respectively positioned in the several reed coils **61**, each preferably above the free end of its reed to be approached and receded from as the reed vibrates. Each reed thus extends and vibrates within the field of its coil, to oscillatorily vary the coil inductance and hence the oscillator frequency. Electrostatic shielding H may again be provided about the oscillator components including the vibrators. A coil **78** may be variably coupled to coil **71** to abstract an output from the oscillator and connected, through potentiometer **42** if desired, to the output terminals **79**.

The oscillation-transmitting means in Figure 3 has been shown as comprising a tuned radio frequency amplifier **56**, and may optionally further include a tunable oscillator and detector **44** and the intermediate frequency amplifier **45** to form a typical super-heterodyne radio receiver. The detector **46**, volume control **48**, audio frequency amplifier **49** and loudspeaker **50** are again employed for the amplifier output; and conductors **47** have been shown connecting the detector **46** back to both the radio frequency amplifier **56** and intermediate frequency amplifier **45** to denote automatic volume control and volume expansion means, either or both of which may be employed if desired. The input of amplifier **56** may be connected through switch **51** and conductors **53** to the oscillator output terminals **79**. The switch **51** may alternatively be thrown to connect the amplifying system of Figure 3 with the string-controlled oscillator **20** of Figure 1, or with conductors **52** hereinafter mentioned.

The general action of the system of Figure 3 will be understood to be analogous to that of the system of Figure 1 as above described, the frequency of maximum transmission of the transmitting means now being understood to be that to which the amplifier **56** is tuned, and the transmission-frequency characteristic (e. g., curve A) to be that of **56**, in combination with **44** and **45** when the latter are employed. The mean frequency of the oscillator **70** may be varied, to properly relate it to the transmission-frequency characteristic, by adjustment of condenser **74**. On the other hand the magnitude of frequency swing of the oscillator **70** may be adjusted by a variation of the inductance in its tuned circuit, which may be done as by varying the coupling between the two coils **72** and **73** in variometer fashion; and if the oscillator mean frequency is to remain constant during this adjustment, the condenser **74** may be compensatingly varied, automatically if desired.

The above described action of the system of Figure 1 was based on operation over a linear portion of the curve A—e. g., on either of its sloping sides S and S'. It is to be noted, however, that variations of this operation are possible, and will produce certain highly useful effects. A particular such variation is the adjustment of the apparatus so that for lower vibrator vibration amplitudes (produced for example by medium and lower hammer velocities in Figure 1) the operation over an essentially linear curve portion will still occur, whereas for higher vibration amplitudes the frequency swing will extend at one or both ends into non-linear portions of the curve. For example, operation may still be effected around the point O on curve A as a mean, but condensers **26** and **38** may be adjusted so that the higher amplitude vibrations, and these only, will cause frequency swings extending to or beyond the point P and correspondingly beyond the "heel" L of the curvé. This adjustment may serve to heighten desirable changes in harmonic structure with tone amplitude, characteristic of many conventional instruments.

In general, harmonic structure control of the output low frequency oscillations from the detector **46**, and hence control of the quality of output tones, may be effected by controlling the

shape of the transmission-frequency characteristic of the transmitting means over the range through which the frequency of the high frequency oscillator swings. This may be done most simply either by adjustment of the magnitude of frequency swing, as mentioned in the preceding paragraph, or by altering the relationship of the oscillator frequency to the frequency of maximum response of the transmitting means—and this latter may be done either by adjustment of the oscillator frequency in the oscillator, or by shifting the frequency of maximum response of the transmitting means (as by adjustment of the interconnected tuning condensers 54 in amplifier 56). A particular adjustment of the apparatus is that which brings the frequency of peak P into coincidence with the oscillator mean frequency, in which case the low frequency output oscillations and tones will all be of doubled frequencies relative to the vibrations producing them.

The controls just described vary the shape which the transmission-frequency characteristic has over the significant range without changing the absolute shape of the characteristic as an entirety—which may for example remain as shown by curve A. A further control of harmonic structure of output tones, however, may be effected by an alteration of the absolute shape of the characteristic, and by the controls above described in conjunction with this alteration. The controllable alteration of absolute shape may for example be effected by various individual adjustments of the individual "trimmer" condensers 55 shown in the several tuned circuits of the amplifier 56. A purely typical transmission-frequency characteristic which may be so established is shown as curve B in Figure 6, characterized by three peaks P_1, P_2 and P_3 of progressively smaller amplitudes. By a tuning adjustment either of the oscillator or of the amplifier (by the interlinked condensers 54) the mean operating point on the curve B may be variously established—as at the point O' on the relatively straight side S' for simple output tones, at point P_1 for doubled frequency effects, or at any point to the left of P_1 for a variety of special effects, the range of which variety may be further extended by a variation of the magnitude of frequency swing. In this connection it is convenient to consider the low frequency oscillator means as one which "sweeps" the transmission-frequency characteristic, about a mean and within limits which may be variously adjusted, the characteristic itself being further susceptible of adjustment.

When the oscillator frequency is made to swing to very substantial extents off of the linear portion of the transmission-frequency characteristic, cross-modulations between tones may occur when chordal playing is indulged in, and the instruments may become best adapted for solo performance. Especially for such performance there may be employed a single low-frequency oscillator selectively operable at a plurality of frequencies and incapable of being operated chordally. While obviously the low-frequency oscillator need not be limited to one of electrical variety, I have shown such an oscillator in Figure 4, the associated high-frequency oscillator whose frequency it varies being connected to leads 52 and thus at will into the amplifier of Figure 3.

In Figure 4 the low frequency oscillator is shown as 80; it may for example be of a type such as disclosed in U. S. Patent No. 1,847,119, to Lertes et al. Typically it may comprise a repeater tube 81; a coupling system 84 including coil 82 connected in the tube input circuit and a coil 83 connected in the tube output circuit; a source 88 of plate potential and a transformer 89 also connected in the output circuit; and an arrangement for applying widely variable grid bias voltage to the tube 81 to control the frequency of its oscillation. This arrangement may comprise a potential source 87 intermediately connected to the cathode of the tube and terminally connected across a resistance element 85; and a stretched wire 86 electrically connected to the lower extremity of the coil 82, normally spaced slightly above the element 85, and depressible at any point therealong against that element, the oscillator being out of operation when the wire is out of contact with the resistance element. Oscillations from the output transformer 89 may be made available at output terminals 91 through a potentiometer 90, and to those output terminals may be connected any of the usual tone quality control means such as schematically indicated at 94, with the variable adjusting devices shown as 92 and 93.

The output from 94 may be connected to the input terminals 101 of the high frequency oscillator 100; this oscillator may be of any form appropriate to frequency modulation by impressed low frequency electric oscillations. Typically it may comprise the tube 21, with plate potential source 24 and by-passed bias resistance 25; coil 108 and condenser 109 forming its tuned input circuit; coil 107 connected in its output circuit and coupled to coil 108; and coils 105 and 106 connected to the input terminals 101 and related to at least the coil 108 in such manner as to vary the frequency of tuning of the oscillator, preferably without effecting any substantial amplitude modulation. Any known means for effecting this result may be employed; as a typical but non-limitative example I have shown the coils 107 and 108 positioned on the central leg 104 of a closed core 103 of special iron-content material suitable for use at high frequencies, and the coils 105 and 106 positioned on the core 103 in an arrangement such that oscillations in the latter coils vary the saturation of the central leg 104 but are opposedly coupled to the coils 107 and 108. An output transformer 110 may transfer the frequency-modulated oscillations from the output circuit of tube 21 to the output terminals 111, to which are connected the conductors 52 leading to the transmission means (e. g., selectively connectible with amplifier 56 as already mentioned).

In instruments wherein the low frequency oscillator means (e. g., the reeds of Figure 3 or the low frequency oscillator 80 of Figure 4) are operated at predeterminable amplitude, adjustment of the magnitude of the high frequency swing will produce a uniform effect on output tone quality. While in Figure 3 an adjustment of this magnitude requires a tuning circuit adjustment in the oscillator, in Figure 4 it is simply accomplished by an adjustment of the potentiometer 90; this simple control therefore becomes a significant control of tone quality, and by it and tuning condenser 109 as independent controls an extremely wide tone quality variation is possible with an irregular transmission-frequency characteristic such as curve B.

While I have disclosed my invention in terms of particular embodiments thereof, it will be un-

derstood that these are intended to be illustrative rather than comprehensive, and that no unnecessary limitations of broader aspects of my invention is intended by their details or by the particular groupings of features therein. In many of the appended claims I undertake to state the scope of my invention broadly, subject however to such proper limitations as the state of the art may impose.

I claim:

1. In a musical instrument, a series of progressively tuned and selectively vibratable vibrators; a high-frequency electrical oscillator having a tuned circuit, said vibrators being physically related to and influencing said circuit to oscillatorily vary the frequency of said oscillator by their vibrations; oscillation-transmitting means fed by said oscillator and having a sloping transmission-frequency characteristic within the frequency range through which said oscillator frequency is varied; and means for demodulating oscillations from said transmitting means to create oscillations of the frequencies of said vibrations.

2. The combination according to claim 1, further including means operable without substantial effect on the mean frequency of said oscillator for adjusting the magnitude of frequency variation thereof effected by said vibrations.

3. In a musical instrument, a series of progressively tuned and selectively vibratable vibrators; a high-frequency electrical oscillator having a tuned circuit including capacity of which said vibrators form an electrode and which is oscillatorily varied by their vibrations to oscillatorily vary the frequency of said oscillator; oscillation-transmitting means fed by said oscillator and having a sloping frequency characteristic within the frequency range through which said oscillator frequency is varied; and means for demodulating oscillations from said transmitting means to create output oscillations of the frequencies of said vibrations.

4. In a musical instrument, a series of progressively tuned and selectively vibratable vibrators; a high-frequency electrical oscillator having a tuned circuit including inductance whose field is intercepted by said vibrators and varied by the vibrations thereof to oscillatorily vary the frequency of said oscillator; oscillation-transmitting means fed by said oscillator and having a sloping frequency characteristic within the frequency range through which said oscillator frequency is varied; and means for demodulating oscillations from said transmitting means to create output oscillations of the frequencies of said vibrators.

5. In a musical instrument, a tuned vibrator arranged for vibration; a high-frequency electrical oscillator having a tuned circuit, a plurality of portions of said vibrator being physically related to and influencing said circuit each to oscillatorily vary the frequency of said oscillator by its vibration; oscillation-transmitting means fed by said oscillator and having a sloping transmission-frequency characteristic within the range through which said oscillator frequency is varied; and means for demodulating oscillations from said transmitting means to create output oscillations of the frequencies of vibration of said vibrator.

6. The combination according to claim 5, further including means for selectively controlling the magnitudes of oscillator frequency variation respectively effected by the several vibrator portions.

7. In a musical instrument, low-frequency oscillator means selectively operable at a plurality of frequencies in accordance with music to be played; a high-frequency electrical oscillator having a tuned circuit determining its frequency of oscillation; means for causing the tuning of said circuit to be oscillatorily varied by said low-frequency oscillator means, whereby to oscillatorily vary the frequency of said high-frequency oscillator; frequency-selective oscillation-transmitting means fed by said high-frequency oscillator; means for demodulating oscillations from said transmitting means to create low-frequency output oscillations; and means, connected with said transmitting means, for varying its transmission-frequency characteristic in the range through which the frequency of said high-frequency oscillator is varied, whereby to control the harmonic structure of said output oscillations.

8. The combination according to claim 7, wherein said last-recited means comprises means for shifting the transmission-frequency characteristic of said transmitting means relative to the range through which the frequency of said high-frequency oscillator is varied.

9. The combination according to claim 7, wherein said last-recited means comprises means for varying the absolute shape of the transmission-frequency characteristic of said transmitting means.

10. In a musical instrument, low-frequency oscillator means selectively operable at a plurality of frequencies in accordance with music to be played; a high-frequency electrical oscillator having a tuned circuit determining its frequency of oscillation; means for causing the tuning of said circuit to be oscillatorily varied by said low-frequency oscillator means, whereby to oscillatorily vary the frequency of said high-frequency oscillator; frequency-selective oscillation-transmitting means fed by said high-frequency oscillator; means for demodulating oscillations from said transmitting means to create low-frequency output oscillations; and means, connected with said high-frequency oscillator, for varying the relationship of its oscillatory frequency variation to the transmission-frequency characteristic of said transmitting means, whereby to control the harmonic structure of said output oscillations.

11. The combination according to claim 10, wherein said last-recited means comprises means for varying the mean tuning of said circuit.

12. The combination according to claim 10, wherein said last-recited means comprises means for varying the magnitude of the oscillatory variations of frequency of said high-frequency oscillator by said low-frequency oscillator means.

13. In a musical instrument, low-frequency oscillator means selectively operable at a plurality of frequencies and at predeterminable amplitudes; a high-frequency electrical oscillator having a tuned circuit determining its frequency of oscillation; means for causing the tuning of said circuit to be oscillatorily varied by said low-frequency oscillator means, whereby to oscillatorily vary the frequency of said high-frequency oscillator; frequency-selective oscillation-transmitting means fed by said high-frequency oscillator; means for demodulating oscillations from said transmitting means to create low-frequency out-

put oscillations; and means, connected with said low-frequency oscillator means, for variously predetermining its amplitudes of operation, whereby to vary the range of frequency variation of said high-frequency oscillator and the harmonic structure of said output oscillations.

14. In a musical instrument, a tuned vibrator arranged for vibration; a plurality of electrodes variously associated with said vibrator and forming therewith a respective plurality of capacities differently varied oscillatorily by said vibration; an electrical circuit; means connecting said capacities into said circuit to render said circuit responsive to the oscillatory variations thereof; and variable condenser means, interposed in said connecting means, for differentially varying the response of said circuit to the variations of the respective capacities while maintaining substantially constant the total capacity of said circuit.

15. In a musical instrument, a tuned string; an element of dielectric material having a convex surface on which said string bears; conductive means in at least substantial contact with another surface of said element whereby to form a capacity with said string; means for exciting a vibration of said string having at least a component normal to said surface whereby to oscillatorily vary said capacity; and an electrical circuit including said capacity and responsive to the oscillatory variations thereof.

16. The combination according to claim 15, further including means for adjusting the bearing of said string on said surface.

17. In a musical instrument, a tuned string; a bridge of dielectric material having a convex surface on which said string bears; conductive means enclosed within said bridge whereby to form a capacity with said string; means for exciting vibration of said string having at least a component normal to said surface whereby to oscillatorily vary said capacity; and an electrical circuit including said capacity and responsive to the oscillatory variations thereof.

18. In a musical instrument, the combination of an oscillation-generating system for producing electric oscillations of complex harmonic structure, said system comprising a tuned string vibratable at a plurality of harmonically related partial frequencies and mechanico-electric translating apparatus responsive to the vibrations of said string; a bridge associated with said system, said string exerting on said bridge a bearing by which qualitative characteristics of said oscillations are influenced; and means, associated with and effective on said string, for varying said bearing whereby to vary said oscillation characteristics.

19. In a musical instrument, a vibratory element, and means for amplifying the sound produced therefrom, comprising a source of superaudible oscillations, a variable reactor, means varying the impedance of said reactor in accordance with said mechanical vibrations, said reactor being connected to modulate the frequency of said oscillations, a transmission channel including means to demodulate said frequency modulated oscillations to derive audio frequency components therefrom, and means to amplify and convert said components into sound waves.

20. In a musical instrument, a vibrating string, a capacity reactance including said string as an element, a source of superaudible oscillations, means modulating the frequency of said oscillations in accordance with variations in capacity of said reactance, a loud speaker adapted to propagate sound waves, a transmission channel including means to demodulate said frequency modulated oscillations to derive audio frequency components therefrom, and means to actuate said loud speaker in accordance with said components.

21. The invention set forth in claim 19 in which the transmission channel includes an amplifier for the modulated oscillations adapted to amplify said oscillations prior to demodulation thereof.

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